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# PRINCIPLES AND METHODS INVOLVED IN DEHYDRATION OF APPLES

by  
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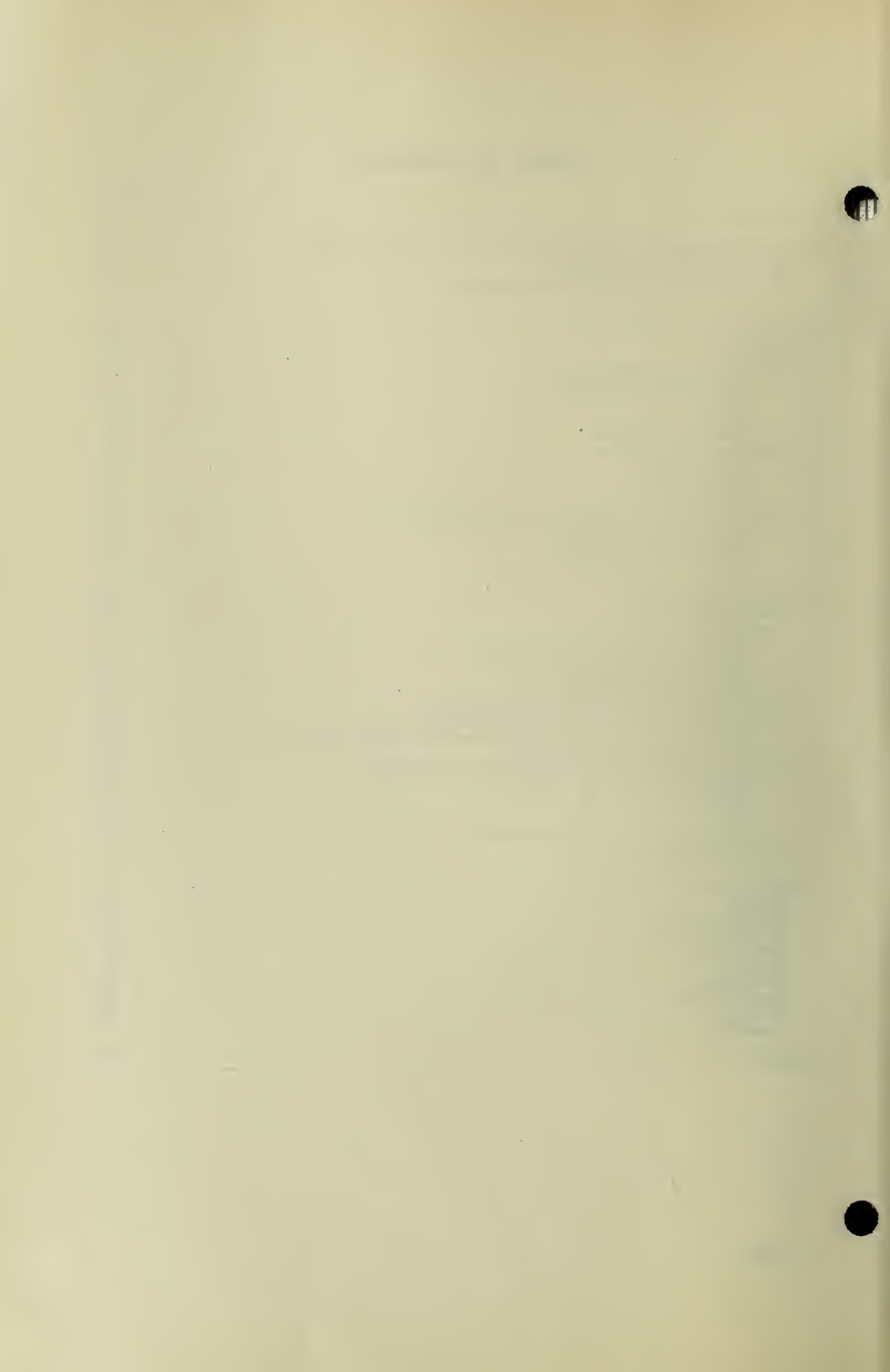
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# DEHYDRATION OF APPLES

BY

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## INTRODUCTION

In any commercial fruit-growing district the disposal of low-grade fruit with a reasonable return to the fruit grower is a problem. If this fruit is dumped on the market as raw fruit the price for the better grades is depressed. Consequently a successful fruit-products industry is necessary to any large fruit-growing district.

In the fruit-growing districts of Nova Scotia the main crop is apples and the fruit-products industry is built around this crop. Plants are in operation for the manufacture of fruit-juice products; apple juice, cider, cider vinegar, cider concentrate; canned goods, both solid and water packs; and dried fruit, both dehydrated and evaporated. By far the largest amount of apples is used up in the manufacture of dried fruit.

### MANUFACTURE OF DRIED AND CANNED APPLES IN NOVA SCOTIA FOR THE YEARS 1931 TO 1936 INCLUSIVE <sup>(1)</sup>

Crop year	Apples used	Processing season	Evaporated and dehydrated	Chips, chop, pomace and waste	Canned apples
	bl.		lb.	lb.	cases
1931.....	.....	1931-32	1,364,371	385,310	7,767
1932.....	254,029	1932-33	1,568,375	176,203	14,508
1933.....	389,449	1933-34	3,410,101	1,529,893	29,866
1934.....	437,012	1934-35	3,777,964	2,060,303	86,115
1935.....	283,466	1935-36	2,415,831	569,897	100,643
1936.....	569,318	1936-37	4,125,449	2,397,790	190,250

<sup>(1)</sup> Figures supplied by the Fruit Commissioner's Office, Dominion Department of Agriculture, Ottawa.

The above figures show a steady increase in the production of dried fruit and a remarkable increase in the volume of canned goods. This is attributable to increased supplies of raw fruit and to wider markets. It is also, to a large degree, accounted for by the improvement of plant equipment. The number of evaporators in operation during this period has been reduced by four, but three new dehydrators have been placed in operation in the Annapolis valley. These have made possible the increase in production of dried apples. In addition to this, in two plants it has been possible to use the old evaporator space to install canning equipment, and this, with the addition of two new canning plants, has been responsible for the increase in the production of canned apples.

This increase in the production of canned apples has used in large volume "C" grade apples and the better grade of culls of the more important varieties. This has been to the detriment of the grade of apples coming into the evaporator plants. It is increasingly important that the grade of apples delivered to fruit product plants be improved, and that apples be paid for on a weight and grade basis.



Any improvement in processing which either makes for more economical manufacture or for a better quality of product is of importance to the industry. The Fruit Products Research Committee (2) have fostered a program of experimentation to determine the best methods of drying fruits.

These investigations were originally carried on in a commercial dehydrator at Grimsby, Ontario, and in a semi-commercial plant at Penticton, B.C. More recently experimental work has been confined to the Dominion Experimental Stations at Summerland, B.C., and Kentville, N.S. At both stations a policy of working with the commercial plants in the locality has been followed. The results of these experiments at Kentville and at commercial plants (3) in Nova Scotia are given in this bulletin.

(2) Present personnel:—

Chairman, Dr. E. S. Archibald, Director, Dominion Experimental Farms.

Col. R. L. Wheeler, Fruit Commissioner.

Mr. M. B. Davis, Dominion Horticulturist.

Mr. C. H. Robinson, Dominion Agricultural Chemist.

(3) Casual visits have been made to all the plants in the Valley. The following have co-operated in the experimental work by making their equipment available for experimental study:—

M. W. Graves & Co., Bridgetown, an original 12-truck single tunnel dehydrator and later a new 8-truck, single-tunnel dehydrator.

United Fruit Cos. of Nova Scotia, Aylesford, an original 12-truck, double-tunnel dehydrator and later a new 7-truck dehydrator with a finishing chamber added.

United Fruit Cos. of Nova Scotia, Port Williams, a 6-kiln evaporator for cost studies.

Kingston Evaporators Ltd., Kingston, N.S., an 8-truck dehydrator using hot-end loading; 5 trucks in the primary end and 3 trucks in the finishing chamber.

## FRUIT REQUIREMENTS FOR ECONOMICAL PRODUCTION AND GOOD QUALITY

### Varieties Suitable for Dehydration

In Nova Scotia the general practice has been to use mixed varieties for drying. This has been due largely to the fact that a great many varieties are grown.

A survey of a single warehouse shows that 72 varieties were packed in one year as follows:—

SURVEY OF A TYPICAL APPLE WAREHOUSE TO SHOW PACKOUT OF BARREL APPLES DURING THE 1931-1932 SHIPPING SEASON (4)

Quantity of each variety handled in barrels	Total quantity packed	Per cent of total barrels handled	Number of varieties represented	Per cent of total number of varieties
Over 1,000.....	42,084 $\frac{3}{4}$	90.9	12	16.7
500-1,000.....	1,740	3.7	2	2.7
100- 500.....	1,393 $\frac{1}{2}$	2.5	6	8.3
50- 100.....	552 $\frac{1}{2}$	1.3	7	9.7
10- 50.....	585 $\frac{1}{4}$	1.4	24	33.3
0- 10.....	95 $\frac{3}{4}$	0.2	21	29.3
Totals.....	46,451 $\frac{3}{4}$		72	

(4) Survey made by R. P. Longley, Agric. Rep., Kings Co., N.S., N. S. Dept. of Agriculture, not published.

These figures are quite typical. They show that although many varieties are shipped, a few varieties represent the largest bulk of apples handled. Figures taken from the total shipments of apples from Nova Scotia up to December 1, 1933, are very similar and twelve varieties represent the great bulk of the fruit so handled. These twelve varieties are: Gravenstein, Ribston,

Blenheim, King, Fallawater, Stark, Golden Russet, Nonpareil, Baldwin, Ben Davis, Northern Spy and Wagener. From these varieties the bulk of the dehydration stock is produced. They could very easily be kept separate, and from them could be manufactured choice stock. The rest of the varieties are received in smaller quantities and could be mixed for the manufacture of standard quality.

To a limited extent this policy has been followed by one plant in the valley. As apples have been received, Stark and Ben Davis have been put in separate heaps. No other increase in cost has resulted. These two varieties have then been dehydrated separately. The finished stock from Ben Davis was white; that from Stark was yellow with a decided greenish cast. In comparison with stock made from mixed apples, both lots were superior and graded choice, as compared with standard grade for the mixed lots. When these lots were sold in England, an average gain of one cent per pound was received from merely separating out these varieties.

Some varieties make better stock than others. The more important varieties have been dehydrated in a small cabinet drier at Kentville. The fall varieties, such as Crimson Beauty, Duchess, and Wealthy, were found unsuitable, due to the large water loss. About eight pounds of prepared apple was found necessary to produce one pound of dried stock. Gravenstein proved to be the first apple of the season suitable for dehydration, with a dry ratio of seven to one. Winter varieties in general gave an excellent dry ratio of six to one or better.

The varieties tested produced different coloured stock. Three main classes were produced: white stock, light golden stock and dark golden stock. In a few cases off-coloured stock was produced.

#### A CLASSIFICATION OF PRINCIPAL VARIETIES ACCORDING TO THE COLOUR OF STOCK PRODUCED AND DRY RATIO

Variety	White	Light golden	Dark golden	White with some pink rings	Greenish cast to rings	Dry ratio
Gravenstein.....		x				7 : 1
Ribston.....		x				5.6 : 1
Blenheim.....			x			6 : 1
King.....		x				6.5 : 1
Fallawater.....		x				
Stark.....					x	6.3 : 1
Golden Russet.....			x			5.8 : 1
Nonpareil.....		x				
Baldwin.....	x				(few)	6.7 : 1
Ben Davis.....	x					6.1 : 1
Northern Spy.....		x				6 : 1
Wagener.....	x					7 : 1

#### ADDITIONAL VARIETIES STUDIED

Wealthy.....				x		7.5 : 1
Maiden's Blush.....	x					
Peewaukee.....			x			
Yellow Belleflower (Bishop Pippin).....		x				6.5 : 1
Rome Beauty.....				x		
Wellington.....	x					
R. I. Greening.....					x	6.2 : 1
McIntosh.....	x					7 : 1

Yellow Belleflower (Bishop Pippin) is not desirable on account of the large core.



The varieties most desirable for dehydration in Nova Scotia are, therefore: Baldwin, Ben Davis and Wagener, for white stock, and Gravenstein, King, Fallawater, Nonpareil and Northern Spy for light golden stock. Stark when dehydrated separately from other varieties makes a very good product but with a greenish cast to the rings.

### Size of Apples for Dehydration

Much has been done to prove that small sizes are unprofitable for dehydration. The Dehydration Committee in a summary (5) of four years' work completed in 1927 report as follows:—

RESULTS OF EXAMINATION OF ONE TON OF FRESH APPLES, EACH OF VARIOUS SIZES AND GRADES

Size	Number of apples in ton	Grade of apples used	Raw stock obtained	Per cent waste	Time to peel and trim	Cost to peel and trim	Quality obtained	Pounds obtained	Selling price
in.			lb.		min.	\$		lb.	\$
1½	42,160	H.P.*	840	58	1,506	12.55	Seconds.....	140	11.20
1¾	26,890	H.P.	940	52	960	8.00	Seconds.....	162	12.96
2	17,149	H.P.	1,080	46	642	5.10	Standard...	180	18.00
2¼	12,608	Cull	1,236	40	450	3.75	Standard...	206	20.60
2½	8,913	Cull	1,000	50	318	2.65	Standard...	166	16.60
2¾	7,261	Cull	1,068	47	260	2.17	Standard...	178	17.80
3	6,004	H.P.	1,440	28	215	1.79	Standard...	240	24.00
3¼	5,118	H.P.	1,490	25.5	183	1.52	Choice.....	248	29.76

\* Hand picked.

The above table very clearly shows that in a ton of fruit there are many more apples to handle in the small sizes than in the larger sizes. This is reflected in the time and cost of trimming one ton of fruit. In addition there is more waste in the smaller size and not until two-inch apples are used is standard grade possible.

At the Dominion Experimental Station, Kentville, various experiments have been conducted on the above. For this work Baldwin, Nonpareil, Wealthy, Gravenstein and Ben Davis were used. The apples were graded on a Cutler grader to vary not more than a quarter of an inch in each size-class. One-hundred-pound lots of each size and of each variety were prepared, the time checked, and the amount of prepared fruit weighed. Duplicate lots were prepared. Average time requirements on the basis of size alone were computed.

The fruit was then dried and the product weighed after moisture had equalized. Cost to produce one pound of dried stock on the basis of preparation alone was figured.

TIME AND COST OF PREPARATION OF APPLES OF DIFFERENT SIZES

Diameter of apples	Time to prepare 100 pounds of fruit	Cost as raw fruit	Cost per pound as dried fruit
in.	min.	ct.	ct.
1¾—2	192.5	96.0	5.86
2—2¼	149.0	74.5	4.47
2¼—2½	101.3	50.6	3.36
2½—2¾	73.0	36.5	2.19
2¾ and up	57.7	28.9	1.73

(5) Bulletin No. 90 N. S., Dept. of Agriculture, Dominion of Canada, "Dehydration of Fruits and Vegetables in Canada."



The figures given must necessarily be considered only comparative, as all operations were with hand machines with labour charged at 30 cents per hour. It is apparent, however, that the smaller sizes are uneconomical to peel and apples under  $2\frac{1}{4}$  inches should not be held for peeler stock.

### Condition of Fruit Required for Dehydration

In addition to size requirements, a reasonably sound fruit is essential to the economical production of good dried stock.

An experiment with commercial runs of fruit was made in a dehydrator at the Aylesford plant of the United Fruit Companies. For this purpose a carload of mixed fruit was graded and shipped from the experimental station in addition to a lot of Domestics of the Baldwin variety. These were run against ordinary warehouse culls. The qualities were as follows:—

*Warehouse Culls.*—An average run of culls from a warehouse which included all sizes mostly between 2 and  $2\frac{3}{4}$  inches, mixed varieties, many badly formed, bruised and pitted fruits.

*Graded Culls.*—Graded to size, all unsound fruit removed, included several varieties. Four size-groups were made: 2 to  $2\frac{1}{4}$  inch,  $2\frac{1}{4}$  to  $2\frac{1}{2}$  inch,  $2\frac{1}{2}$  to  $2\frac{3}{4}$  inch, and  $2\frac{3}{4}$  inches and up.

*Domestics.*—One variety, Baldwin, size  $2\frac{1}{4}$  to  $2\frac{3}{4}$  inches, domestic grade, except for common scab, which did not affect paring quality.

Each lot was run separately. In the case of graded culls, each size was considered as a lot. The time required to pare and trim was taken. All waste from each lot was weighed and the product of each lot was kept separate. The following table shows the results.

THE EFFECT OF GRADE AND SIZE ON PLANT CAPACITY, COST OF PREPARATION AND YIELD OF DRIED STOCK

Type of fruit used	Daily plant capacity*	Waste	Cost of preparation of 100 barrels	Yield of dried fruit per 100 barrels	Per cent whole rings
	bbl.	%	\$	lb.	%
Graded cull, $2\frac{3}{4}$ inch and up**	413	26.9	12.17	1,617	62.5
Graded cull, $2\frac{1}{4}$ — $2\frac{3}{4}$ inches	469	31.5	11.80	1,520	60.9
Domestics, $2\frac{1}{4}$ — $2\frac{3}{4}$ inches	391	20.9	12.29	1,538	61.4
Graded cull, $2\frac{1}{4}$ — $2\frac{1}{2}$ inches	346	34.1	13.99	1,462	60.9
Graded cull, 2— $2\frac{1}{4}$ inches	234	38.7	20.48	1,361	43.8
Warehouse cull, all sizes	229	35.8	21.00	1,425	52.0

\*The plant was equipped with eight double-unit paring machines; the capacity of these machines to pare fruit of the different grades and sizes is given on the basis of a ten-hour working day.

\*\*It was found that apples over three inches in diameter did not peel well in power machines. In many cases they jammed in the coring knife and much time was lost in clearing the machines. There was an unexpected decrease in the rate at which this grade could be pared, for this reason.

The influence of size of fruit on cost of preparation is again illustrated under commercial conditions.

The warehouse cull with its small-sized, badly formed and bruised fruit gave no better results than the smallest sizes.

Graded culls and domestics show a decided advantage in manufacture and the finished quality of the product is better than that from ungraded stock due to the larger percentage of whole rings and the greater uniformity of stock.

The figures on plant capacity show that daily production can be seriously affected by using low-grade fruit.

Graded culls could be secured by simply offering a premium for them and both the grower and the manufacturer would gain by it.

If, for example,  $2\frac{1}{4}$  to  $2\frac{3}{4}$  inch grade domestics, equivalent to graded culls for this purpose, are compared with the warehouse cull, the following values are secured.

**VALUE OF DOMESTICS OR GRADED CULLS OVER THE ORDINARY CULL FOR DEHYDRATION**

Item	Value
Paring cost saved per hundred barrels.. . . .	\$ 8 81
Increased yield with no additional cost except paring, 113 pounds at 7 cents.. . . .	7 91
Increased yield of rings over chop.. . . .	2 04
Reduction in overhead per 100 barrels.. . . .	8 00
Total increased value.. . . .	\$ 26 76

The above does not take into account any increase in value or demand for the improved finished product. It is apparent that at existing prices, which are very low, a 25-cent premium per barrel could be paid for good stock for dehydration.

It is uneconomical to pare deformed, badly bruised or unsound fruit. The yield is small and it lowers the final grade of the product.

To improve the grade of Canadian dried apples, it is necessary that fruit be purchased on a grade and weight basis. At present the quality of fruit coming into the plants almost entirely regulates the quality of the finished goods that are produced. This is particularly true in Nova Scotia.

With competition keen for the raw fruit, and canners utilizing the best grade of culls, stock for dehydration must suffer unless a grade system is established. This would ensure an adequate return to the fruitgrower and would make it worth while to look after the low grades of fruit properly. To the processor it would ensure adequate supplies of better-quality fruit and an improvement in the finished quality of his goods.

### THE MECHANICS OF DEHYDRATION

The next important step is to have suitable equipment to process the fruit, to preserve as nearly as possible its natural qualities. Processing is a very exact physical operation and the equipment must be so constructed as to give control of heat, air volume and humidity at all stages during the drying operation. Cost is a most important factor and the equipment must be efficient.

#### Definitions

*Dehydration.*—From an industrial standpoint is the removal of water from a product under controlled conditions of air flow, temperature and humidity. The dehydrator is the equipment used for this control.

*Evaporation.*—From an industrial standpoint is the removal of water from a product where only casual control of air flow, temperature and humidity can be made. The ordinary commercial evaporator is typical of this method of drying.

#### Historical

Originally drying was carried on as a fruitgrower's operation. Pared and cored slices were simply strung up behind the stove or in a warm place to dry.

With the growth of the fruit industry, commercial evaporators or kiln driers were established and many of these are still in operation. The kiln proper is built in a two-storey arrangement. In the lower or basement floor a large stove or furnace is placed with the fume pipe leading around the room to a



chimney at its side. The pipes are so arranged that heat is fairly equally distributed underneath the ceiling. The ceiling is made of narrow slats with sufficient space between them to allow the passage of air up into the second floor. On this slatted floor prepared rings are spread evenly to a depth of from five to eight inches, depending on the maturity of the fruit and the variety used. Softer fruit is spread rather thinly compared with crisper fruit. To facilitate air movement, four intake ducts are usually cut in the lower part of the basement walls, and on the room above, a sloping roof is built to a large outlet duct which allows the saturated air to pass to the outside. The fruit is turned two or three times during the drying operation. The movement of air is entirely dependent on the convection principle and very little can be done to regulate the passage of air through the fruit. The drying operation usually takes from 18 to 24 hours. Most evaporators in Nova Scotia are built to handle 25 to 30 sugar barrels of prepared fruit in each kiln at each loading.

Evaporators have usually been fired with hard wood or coke in Nova Scotia. Two concerns have substituted heavy furnace or crude oil as a heat source. Operation with this form of fuel has been very satisfactory. Although fuel costs have remained approximately the same, the oil requires much less handling and a more uniform heat can be supplied. The result has been an increase in the rate of drying so that kilns, which formerly took from 16 to 20 hours to dry, are now dried in from 12 to 14 hours.

With the development of the prune industry in Western Canada and the United States, dehydrators were developed that were adapted to this product. On the strength of their success in the prune drying industry three dehydrators were built in Nova Scotia. One was of the single-tunnel type and two of the double-tunnel type. These have operated with only fair success.

Recently new dehydrators have been constructed in Nova Scotia based on an accumulation of experimental evidence. These are specially designed to meet the requirements of apple dehydration.

### **Evaporation versus Dehydration**

In the past in Nova Scotia evaporators have been popular. They have provided a fairly efficient unit for the drying of fruit. Their initial cost has been low and they have been able to produce a fairly satisfactory product at moderate cost. The older dehydrators were very little better than the evaporators. With the modern dehydrator advantages have been secured.

#### **RELATIVE COST OF EQUIPMENT**

Exclusive of building, the dehydrator is more costly to install than the evaporator. To fit up a four-kiln evaporator would probably cost around \$1,500. A thoroughly modern dehydrator can be built for approximately \$4,000, with an additional \$1,000 necessary for boiler-room fittings. On the basis of production this additional cost entirely disappears. A four-kiln evaporator would have a daily capacity of around two tons of dried stock per day. The dehydrator would have a capacity of two and one-half tons when paring machines are operated ten hours a day, and double this when two shifts are used and the dehydrator is operated continuously.

#### **RELATIVE COST TO OPERATE**

Drying costs have been checked in five commercial drying plants in Nova Scotia. *Plant A* was a two-tunnel dehydrator, both tunnels served by a single fan. Each tunnel held six trucks fed lengthwise through the tunnel, making a total distance air was circulated over fruit of 36 feet. The fan was driven by a 20 h.p. electric motor. *Plant B* was a single-tunnel dehydrator served with one fan. This is driven by a 30 h.p. steam engine, direct drive. The exhaust



steam is used in low-pressure heaters to supply a large part of the heat for the drying operations. The tunnel holds seven trucks placed crosswise of the tunnel. The total distance of air flow over fruit is 28 feet. The coal used was slack. *Plant C* was a commercial evaporator with heat supplied as hot air. The form of fuel used was coke. *Plant D* was a dehydrator of the single-tunnel type with a primary tunnel and one finishing chamber. Power was supplied by a 30 h.p. steam engine and the exhaust steam used for heat. Temperature control is supplied at both ends of the dehydrator. *Plant E* was an evaporator using bunker oil as the source of heat.

COST FOR FUEL AND ENERGY TO DRY FRUITS IN FIVE COMMERCIAL PLANTS

	Average daily pro- duction	Average daily coal con- sumption	Value of coal per ton	Daily coal cost	Average daily power con- sumption	Total cost	Cost for heat and energy to dry one pound of fruit
	lb.	lb.	\$	\$	\$	\$	ct.
Plant A.....	3,109	7,830	6.00	23.49	4.50	27.99	0.90
Plant B.....	3,842	4,134	4.10	8.48	Nil	8.48	0.22
Plant C*.....	1,730	1,988	8.00	7.45	Nil	7.95	0.46
Plant D.....	Operator's figures					.....	0.34
Plant E.....	Oil- fired Operator's figures					.....	0.54

\* Figures taken for two kilns only.

In cost per pound the efficiently operated modern type of dehydrator costs much less per pound of dried stock than either the evaporator or the two-tunnel dehydrator. The cost for the evaporator (*Plant E*) is low compared with that of most evaporators. From the figures above it is safe to assume that a carefully operated dehydrator can produce dried stock for about one-half to two-thirds the cost in an evaporator.

QUALITY

More whole rings are produced in dehydration than in evaporation. In evaporators fruit is turned over two or three times during the drying operation. This tends to break up the rings. In the dehydrator, fruit is placed on trays and not touched until the fruit is dried. For the same reason dehydration tends to be more sanitary. There is no walking over kiln floors or shovelling over of partly dried fruit.

The colour of the rings is also superior. With the most recent installation hot-end loading is used. This is explained later. The natural colour of the fruit is fully preserved in the dehydrator. In the evaporator there is always more or less discoloring due to slow oxidation during the long drying process, in addition to smoke and discoloration from the kiln floor.

OPERATION ADVANTAGES

The dehydrator lends itself to continuous operation. It is not so subject to weather conditions or to the state of the raw fruit. On days when the humidity is high, evaporation is materially slowed up in a kiln drier. With very ripe, comparatively soft fruit the rings tend to bed down, blocking the air flow. Neither of these conditions obtain with the dehydrator.

In addition to the above the fire hazard is very largely reduced with dehydrators. Due to the fact that the walls of the evaporator become very dry and that stack temperatures are apt to become very high, the risk of fire is great and insurance for this type of plant is costly.

During the past eight years, out of a total of ten evaporators in operation at that time, five have been destroyed by fire. Of five dehydrators in four plants, one has been destroyed, and this was caused from spread of fire from an adjacent building.

### Principles of Dehydration

As explained in the section on definitions, dehydration is the drying under controlled conditions of air flow, temperature and humidity. A knowledge of the function of each is essential to the operation of a dehydrator.

#### FUNCTION OF AIR

Air is the common medium used in drying, although other methods might be used, such as drying in vacuo. It is the easiest medium to use and has two functions. It conveys the heat from the heating units to the product to be dried. Here it picks up moisture and then performs its second function of acting as a carrier for this moisture, and the moisture is thus transported to the outside air. A given amount of air passing over moist surfaces drops in temperature (dry-bulb reading) just in proportion to the amount of moisture picked up. Other conditions being equal, therefore, the rate of drying is directly affected by the volume of air passing over the fruit.

#### FUNCTION OF HEAT

As stated above, air merely acts as a carrier for heat and moisture. Heat is essential to the drying operation and just in proportion to the heat lost in passing over the fruit is moisture picked up and carried away from the fruit. The conditions producing this are fixed by definite physical laws. Approximately 1,000 British thermal units of heat are required to change one pound of water to water vapour; this is the latent heat of vaporization and is a fixed value whether vapour is formed at or below the boiling point. A British thermal unit is a standard of measurement of heat. It requires one British thermal unit (1 B.t.u.) of heat to raise one pound of water one degree Fahrenheit. Or conversely one British thermal unit of heat is liberated when the temperature of one pound of water is lowered one degree.

Air expands on heating and there is less actual air in a cubic foot at a higher temperature than at a lower one. The generally accepted figure for air is that .01807 B.t.u. of heat is released as one cubic foot of air drops one degree Fahrenheit, and the converse is of course true. This figure varies with temperature but for purposes of approximate calculation is sufficiently accurate.

In a commercial dehydrator a cross section of the tunnel was six feet by seven feet, or 42 square feet. Air velocity measurements showed that the air velocity was 1,040 feet per minute. Then 42,680 cubic feet of air was passing over the fruit each minute. The air temperature as it entered the fruit trays was 167 degrees Fahrenheit; as it left the trays the temperature was 122 degrees Fahrenheit, both dry-bulb readings. The actual temperature drop was 45 degrees Fahrenheit in passing over the fruit. Each cubic foot of air dropping one degree Fahrenheit releases .01807 B.t.u. of heat.

∴ Volume of air per minute  $\times$  degrees drop in temperature  $\times$  .01807 equals the number of B.t.u. of heat released.

As this heat is used in changing water in the fruit to vapour and 1,000 B.t.u. are necessary to vaporize one pound of water,

Volume of air per minute  $\times$  degree drop in temperature  $\times$  .01807 equals the

∴ 
$$\frac{42680 \times 45 \times .01807}{1000} = 34.70$$
 pounds of water evaporated per minute or the evaporation rate. In this case



From this formula the capacity of the plant can be calculated. Each truck has 1,200 pounds of prepared fruit loaded on it. If the dry ratio is approximately six to one, the amount of water to be evaporated from this truck is 1,000 pounds. Each time a truck is added 1,000 pounds of water to be evaporated is

added. In this drier, therefore, a truck of fruit can be placed every  $\frac{1000}{34.70}$  or 29 minutes.

In practice this calculation was found to be approximately correct. The machine was shut down each time a truck was added for approximately four minutes and it was found that the average time between adding trucks was 35 minutes.

#### HUMIDITY OF AIR

*Determination of Humidity.*—Humidity of air can only be taken in relation to temperature. It is determined by the use of wet- and dry-bulb thermometers. The dry-bulb reading is the temperature of the air. The wet-bulb reading is a depressed reading due to the evaporation of moisture from the sack surrounding the mercury.

Relative humidity is calculated from these two readings by the use of a psychrometric chart or humidity table as follows:—



RELATIVE HUMIDITY TABLE (6)

Deg. F. temp.	Wet bulb temperatures, degrees Fahrenheit																			
	215	210	205	200	195	190	185	180	175	170	165	160	155	150	145	140	135	130	125	120
215.....	100	91	82	73	66	60	55	47	42	37	32	29	25	22	19	16	14	12	10	8
210.....	100	100	90	81	73	66	58	52	46	41	36	32	28	24	21	18	16	13	11	9
205.....	100	100	100	90	81	72	65	58	51	45	40	35	31	27	23	20	17	14	12	10
200.....	100	100	100	100	90	81	72	64	57	51	45	39	34	30	26	22	19	16	14	11
195.....	100	100	100	100	100	90	80	72	64	57	50	44	38	33	29	25	21	18	15	13
190.....	100	100	100	100	100	100	90	80	71	63	57	49	43	37	32	28	24	20	17	14
185.....	100	100	100	100	100	100	100	90	80	71	62	55	48	42	37	31	27	23	19	16
180.....	100	100	100	100	100	100	100	100	89	79	70	62	54	47	41	35	31	26	22	18
175.....	100	100	100	100	100	100	100	100	100	88	78	69	61	58	46	40	35	30	25	21
170.....	100	100	100	100	100	100	100	100	100	100	89	78	69	60	52	45	39	33	28	24
165.....	100	100	100	100	100	100	100	100	100	100	100	88	78	68	59	49	44	38	32	27
160.....	100	100	100	100	100	100	100	100	100	100	100	100	88	77	66	57	50	43	37	31
155.....	100	100	100	100	100	100	100	100	100	100	100	100	100	88	77	66	57	49	42	36
150.....	100	100	100	100	100	100	100	100	100	100	100	100	100	88	77	66	57	49	42	36
145.....	100	100	100	100	100	100	100	100	100	100	100	100	100	100	87	75	66	57	48	41
140.....	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	87	75	64	54
135.....	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	86	74	63
130.....	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	86	73
125.....	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	86

(6) Taken from Dominion Department of Agriculture, Bulletin No. 151 N.S. with some additional readings.

If the temperature of air at the hot end of the tunnel is set at 180 degrees F. and readings are taken, typical readings would probably be: dry-bulb, 180 degrees F., wet-bulb, 115 degrees F. To determine relative humidity from the chart read down the left hand column—dry-bulb temperatures—until 180 degrees F. is reached, then read straight across until the figure directly below the wet-bulb reading 115 degrees F.—at top of chart. This would give the figure 14, or the relative humidity at these readings. If the wet bulb were 117 degrees F. instead of 115 degrees F. the reading would be approximately intermediate between the figure for humidity at 120 degrees F. wet-bulb, which is 18, and 115 degrees F., which is 14, or a relative humidity of 16.

*Effects of Humidity.*—In dehydration humidity has several effects. The lower the humidity the greater the absorptive power of air, and the rate of moisture removal is more rapid at the low than at the high humidity. In some cases this does not follow due to physical effects on the fruit itself. Moisture is taken from the surface of the fruit more quickly than it can be carried from the inside. The result is "case hardened" fruit or fruit with a dry outside layer. In experimental tests at the Kentville experimental station, case hardening has only been produced with apples when most exceptional conditions have been produced.

In practical dehydration the humidity of the air that is released has a great deal to do with economical dehydration. As heated air passes over the fruit the dry-bulb is depressed whereas the wet-bulb remains almost constant at all points in the dehydrator for one given set of readings. The relative humidity therefore increases.

As explained previously depression of the dry-bulb is due to work done by the heat of the air evaporating water. If the temperature at the hot end of the tunnel were 180 degrees F. dry-bulb, and 122 degrees F. wet-bulb, and passing over the fruit the air did its full job, the reading at the cool end would be, theoretically, 122 degrees F. dry-bulb and 122 degrees F. wet-bulb, or 100 R.H. At any intermediate point the wet-bulb would be at a constant of 122 degrees F. A depression of the wet-bulb in this case, say from 122 degrees F. to 119 degrees F., would indicate heat loss through the walls of the dehydrator, heating the trucks, etc., where no moisture is being absorbed. In practice this depression should not be over one or two degrees.

In the operation of a dehydrator, to get greatest efficiency air should be carrying its maximum load of moisture before it is released, otherwise high fuel costs result. In commercial operation air at usual temperatures has lost most of its drying power when a relative humidity of 65 to 75 is reached. At this point outlet dampers should be opened and a part of the air released and the rest recirculated. It is not necessary to release all of this air as much less is required to carry moisture than to conduct heat.

If air entered the dehydrator as dry air and left the dehydrator with a normal drop in temperature, about seven times the volume of air would be necessary to evaporate one pound of water than would be required to transport it away from the fruit to the outside of the dehydrator. In operation where air enters the dehydrator carrying a certain amount of moisture and where full saturation of the air is not obtained, it is found that one-quarter to one-third of the volume of air circulating is usually released when the dehydrator is running to capacity.

## Physical Conditions Necessary to Secure a Good Product

### AIR VELOCITY REQUIREMENTS

To determine the factors influencing quality different lots of the same variety have been dehydrated under controlled conditions. Temperature, humidity, and rate of air flow are factors that influence the quality of fruit.



Only the first two have been worked on, the rate of air flow having been kept constant for all dehydrations. It is apparent that reasonable air flow is necessary to a good-quality product, as fruit should be dried quickly to reduce the length of time in which oxidation may occur. In practical operation air velocity of 800 feet per minute or better has given excellent results. When velocities have been much over 1,000 feet per minute, static pressures have been so increased that energy costs to drive the fan have been excessive.

TEMPERATURE REQUIREMENTS

In general the rate of drying increases directly with the temperature. To get capacity and ensure quick drying it is desirable to use as high temperatures as possible and yet not discolour the product. To determine this various temperature conditions have been used as follows:—

TEMPERATURE RANGE IN DEGREES FAHRENHEIT FOR DEHYDRATIONS

Start (first two hours)	Middle	Finish (last two hours)
High.....175—190	High.....175—180	Medium.....155—175
Low.....145—165	Medium.....165—170	High.....175—185
Low.....145—165	High.....175—180	Low.....155—165

Four dehydrations were made under each set of conditions in a small cabinet drier. The final qualities were determined.

THE EFFECT OF TEMPERATURE ON QUALITY OF DRIED FRUIT PRODUCED

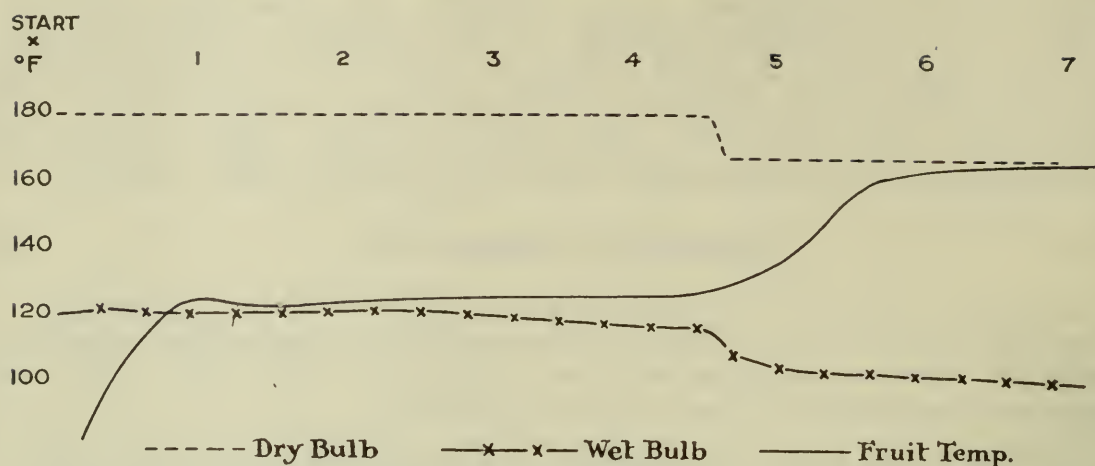
Lot number	Temperature conditions			Final quality
	Start	Middle	Finish	
	°F.	°F.	°F.	
1.....	180	180	175	Scorched.
2.....	190	180	155	Excellent.
3.....	175	175	173	Scorched.
4.....	180	180	170	Excellent.
5.....	165	170	185	Badly scorched.
6.....	145	155	180	Badly scorched.
7.....	160	160	175	Scorched.
8.....	150	170	180	Badly scorched.
9.....	165	180	155	Good.
10.....	145	175	165	Good.
11.....	155	175	165	Good.
12.....	160	180	160	Good.

The last two hours of drying, and particularly the last hour, are the important periods in drying. In no instance under the above conditions was case hardening produced with a high early temperature. The rate of drying was directly accelerated by a high early temperature, and scorching did not result at this time. During the last period of drying a high temperature produced scorching or browning in every instance. A temperature in excess of 165 degrees Fahrenheit tended to brown fruit. In the operation of a commercial dehydrator it was found that with extreme care in removing the trucks at the right time 170 degrees F. could be used.

It is apparent that as fruit dries, the danger of scorching with high temperature is increased. The reason for this is associated with the actual temperature of fruit during the drying process.



The following graph illustrates the condition.



Variation of Fruit Temperatures during Dehydration in Relation to Wet- and Dry-Bulb Readings

During the early stages of drying the fruit slices were very nearly the temperature of the wet-bulb thermometer due to evaporation. As the fruit approached dryness evaporation was materially slowed up. The temperature of the fruit, therefore, rose toward the temperature of the dry-bulb thermometer. During the last stages of drying the temperature was only slightly lower than the dry-bulb thermometer reading. If temperatures at this time are above the caramelization point of sugar, browning necessarily follows.

#### HUMIDITY REQUIREMENTS

Studies of humidity showed the following conditions. Very high humidity at the start of the drying period tended to brownish discoloration of the rings. In a commercial dehydrator where the trucks were placed in the cool end of the tunnel, very high humidity caused condensation of moisture on each truck as it was placed in the tunnel and discoloration from drip resulted.

Medium humidity (20 to 32 degrees relative) with high temperature produced quick drying without browning in the early stages of drying. High humidity and low temperature delayed drying more than low humidity with high temperature.

#### COMMERCIAL DEHYDRATORS

The dehydrators originally operated in Nova Scotia were constructed after driers designed and used for prune drying. Here a low temperature is required in the early stages of drying so the fruit is loaded at the cool end of the tunnel. As the prune gives up its moisture but slowly and saturation of air is not quickly reached, the tunnels were built either as double tunnels six trucks long and the trucks placed end to end, or as single tunnels with the tunnel twelve trucks long and the trucks placed crosswise of the tunnel. In either case the air passes over a long stretch of fruit, being 36 feet in the first case and 48 feet in the second. This is ideal for this class of fruit.

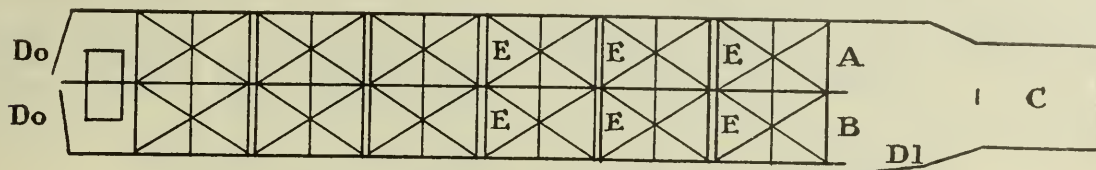
The apple on the other hand gives up its moisture very quickly, and much more moisture is taken from apples than from prunes. This means that a dehydrator designed for prune drying may not be ideal for apple drying and this was found to be the case.

#### The Double Tunnel

This tunnel served by one fan obviously has some disadvantages. Unless both tunnels are kept with the same number of trucks in each tunnel the air tends to by-pass through the tunnel with the lesser load. In addition the fruit

on the side of the truck nearer the heat source has always dried faster. With the type of trucks used, i.e., with one stack of trays behind the other on the same truck, each truck had to be turned when one stack of trays was dry in order to get the other stack dried to a similar moisture content.

These difficulties were not encountered in the single-truck tunnel.



Plan of Double Tunnel. A and B, two tunnels served by one fan, C; Do, entrance doors; D1, door from which fruit trucks are removed; air return and heaters over the top of the dehydrator; E, trucks, six to each tunnel. Trucks entered at Do and finished at other end; air flow in the opposite direction. Scale 10 feet to 1 inch.

### The Single Tunnel

The single tunnel has several advantages in operation.

#### EVENNESS OF AIR FLOW

Even air flow is essential in all parts of a drier to ensure uniform drying. With one fan serving one tunnel this can be secured by spacing the fan outlet at a reasonable distance from the first truck. It is essential that the air be forced evenly between the trays from top to bottom and from side to side. Too much space above the trucks or underneath or beside the trucks allows air to bypass freely. This allows air to pass through the tunnels without doing any work.

In a tunnel examined where this was occurring, air was passing over the trucks at a rate of 1,500 feet per minute and under the trucks at a rate of 1,000 feet per minute. The air velocity through the trays averaged from 400 to 500 feet per minute.

Baffle boards were placed opposite each truck to obstruct these free passages. The air velocity was then increased through the trays to between 700 and 800 feet per minute with a corresponding speeding up of the drying rate.

In addition to the above, a low humidity of the air at the leaving end of the tunnel resulted. The working air that passed over the fruit had picked up moisture and was commercially saturated. The by-passed air was very nearly the temperature of the air leaving the fan. These two airs mixing resulted in only moderate humidity at the leaving end, in this case 32 degrees R.H. If all this air is re-circulated no heat loss results but if outlet dampers are open, all the air being discharged represents a heat loss which is reflected in higher coal consumption per pound of dried fruit produced.

#### LENGTH OF TUNNEL FOR DRYING APPLES

When the twelve-truck tunnel is fully loaded under Nova Scotia conditions, very little if any drying occurs in the trucks placed at the cool end until they have been worked up four or five trucks from this position. In fact, marked deterioration of the fruit occurs and it often takes on a water-soaked appearance before drying actually occurs. In some cases severe drip occurred. The fruit is often prepared at a low fruit temperature in Nova Scotia due to severe winter conditions. When these trucks are added to the end of the tunnel where the air is at high humidity the air is chilled below the dew point. Condensation of moisture occurs on the rings followed by sugar loss, drip and discoloration of the rings.



To determine the ideal load for a tunnel of this type a commercial tunnel was operated with from three to nine trucks in the dehydrator at one time. The fan for all operations was kept at a constant speed of 400 r.p.m.

#### TUNNEL EFFICIENCY WITH FROM THREE TO NINE TRUCKS IN THE DEHYDRATOR

Number of trucks	Air velocity	Heated air leaving fan			Air leaving fruit			Dry bulb depression	Water* evaporated
		Dry-bulb	Wet-bulb	R.H.	Dry-bulb	Wet-bulb	R.H.		
	ft.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	lb.
3.....	1,200								
4.....	1,120	167	110	20	128	110	47	39	33.1
5.....	1,050	167	111	20	125	110	54	42	33.8
6.....	1,040	167	112	21	122	111	67	45	34.7
7.....	990	166	113	22	122	112	74	44	33.0
8.....	900	166	114	23	122	113	74	44	29.2
9.....	850	166	115	24	122	114	82	44	27.8

\* Water evaporated in pounds per minute according to the formula.

$$\frac{\text{Volume of air (cu. ft.)} \times \text{Depression of dry bulb,}}{\text{degrees Fahrenheit} \times .01807} = \frac{\text{pounds of water}}{\text{evaporated per minute}}$$

Volume of air per minute = Velocity of air  $\times$  42, as the tunnel is 6 feet by 7 feet in cross section.

The above data show that as trucks were added the velocity of air circulated through the trucks decreased. This is natural, as each added truck would increase air resistance and this would only be overcome by increasing the r.p.m. of the fan. The temperature of the air entering the trays was kept as nearly constant as possible at 167 to 166 degrees Fahrenheit, but as trucks were added the wet-bulb readings increased from 110 degrees F. to 115 degrees F. The dry-bulb depression, hot end to cool end, rapidly increased until six trucks were in the tunnel. As this along with the air velocity is an accurate index of the speed of drying, six trucks was the ideal load from this standpoint. The relative humidity of the leaving air also increased and not until six trucks were added was reasonable commercial saturation of air secured. In addition the calculated efficiency of this tunnel on the basis of evaporation of water per minute showed that six trucks gave quickest drying.

When more than seven trucks were added, condensation began to occur on the additional trucks.

For the conditions of operation it is concluded six trucks or 24 feet of fruit is sufficient to ensure commercial saturation of air and to get most rapid drying. If air speeds were increased the number of trucks could be increased; the converse would also be true.

Trays in this case were  $3\frac{1}{4}$  inches high with a space for the passage of air of  $2\frac{1}{4}$  inches between trays.

#### EFFECT OF FRUIT LOAD ON DRYING

The amount of fruit placed on each tray has a direct effect on the rate and efficiency of drying. An overload of fruit blocks the air passages between the trays and cuts down air velocity and the volume of air passing over the fruit. When three different rates of loading were tried,  $1\frac{1}{2}$ , 2 and  $2\frac{1}{2}$  pounds per square foot of tray surface, two pounds was found to be the maximum load that could be used. With this load when the fruit was trayed evenly over the entire tray surface, quick, even drying resulted. Unevenly loaded trays tend to channel the air and make for patchy drying.



## AIR AND FAN REQUIREMENTS

For this type of drier a fan of a capacity of 40,000 cubic feet at two-inch static pressure and 450 r.p.m. gives good capacity. The fan should be of the non-overloading, multivane type to work satisfactorily where considerable resistance to the air flow is developed. Under some conditions it may be found advisable to drive the fan with a steam engine and use the exhaust steam for heat to dry the fruit. A dehydrator of this capacity should dry from two and a half to three tons of dried stock per day.

**Hot-end and Cool-end Loadings of Dehydrators**

The original dehydrators in Nova Scotia have all been loaded from the cool end of the tunnel and the trucks moved up against the air current to the hot end of the tunnel. The evidence from control dehydrations in a cabinet drier (see page 17) shows that for apples this procedure is wrong, and that apples should be dried as quickly as possible at a comparatively high temperature in the early stages of the drying and then the heat should be lowered as the apples approach dryness in order to prevent caramelization of sugars. This can be done by entering trucks of fruit at the hot end of the tunnel and moving them with the air current as they dry to the cool end of the tunnel. Cruess (7) as early as 1924 suggests that apples lend themselves to this procedure, "the parallel system of loading."

(7) Cruess, W. V., Commercial Fruit and Vegetable Products. McGraw Hill Book Co., New York, pages 373 and 394.

## THE SINGLE SHORT TUNNEL LOADED AT HOT END

This was done in a single short tunnel dehydrator designed to dry apples. The temperature at the hot end of the tunnel was first set at 200 degrees F. and the wet-bulb reading was found to be 122 degrees F., with a relative humidity of 11. A truck was placed in the tunnel every 30 minutes. The results were as follows:

## TUNNEL EFFICIENCY USING 3 TO 7 TRUCKS AND HOT-END LOADING

Number of trucks	Air velocity per minute	Air, leaving temperature		Depression of dry-bulb	R.H. of leaving air
		Dry-bulb	Wet-bulb		
	ft.	°F.	°F.	°F.	
3.....	1,200	155	124	44	41
4.....	1,160	152	124	46	44
5.....	1,100	148	123	52	48
6.....	1,090	144	123	56	53
7.....	1,020	141	123	59	56
Air temperature of entering air reduced to 180 degrees F. dry-bulb, 112 degrees F. wet-bulb, and R.H. 11.					
7.....	1,020	128	113	52	62

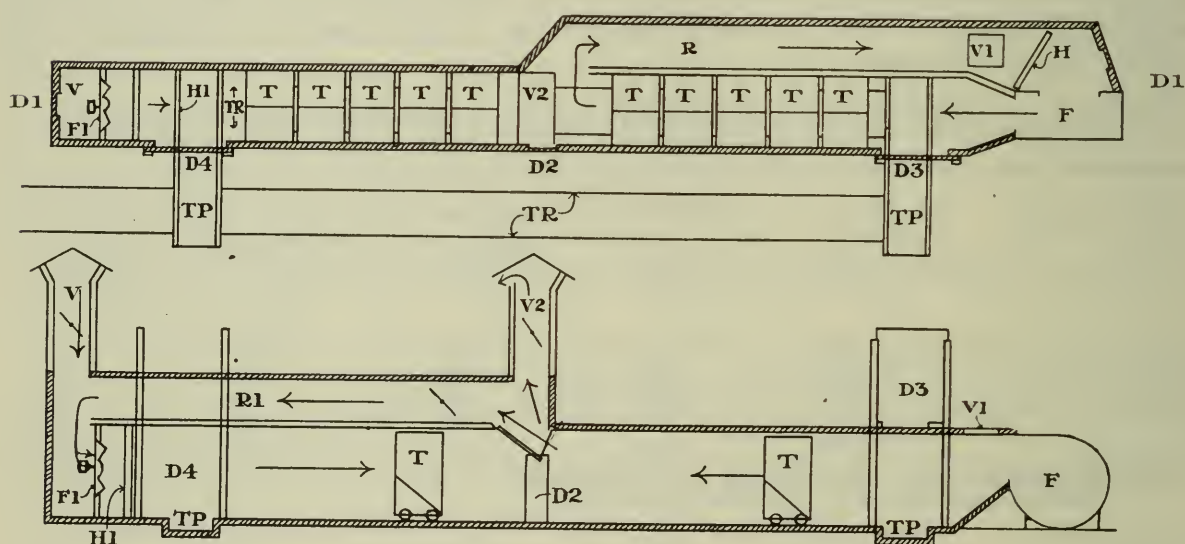
*Efficiency.*—The data are in general agreement with those taken for cool-end loading. The air velocity was not depressed as much as where cool-end loading was used. This is attributed to a rapid flattening out of the rings due to evaporation in hot-end loading, whereas in cool-end loading the rings dry very slowly at first. The resistance to air flow is reduced in hot-end loading. Reasonable saturation of the air was secured by lowering the entering air temperatures after seven trucks had been placed in the tunnel. Very quick drying resulted from this method of handling.

*Quality of Product.*—A comparison of the finished product under the two methods of drying showed a superior product when trucks are fed from the hot to the cool end of the tunnel. The colour was much whiter and instead of a brittle ring, the material took on a velvety feel with much less tendency to break when taken off the trays.

*Weakness of Method.*—From a physical standpoint this method was impracticable in the dehydrator as designed. Commercial saturation of air was secured, quick drying and excellent colour was produced. The one difficulty was to secure even drying of the trucks. As explained previously the fruit on the side of the trays nearer the heat dried more quickly. In this method of loading this condition was very marked. When the truck had come to its final position one side would be sufficiently dry while the other was still not dry enough. At this end of the tunnel the drying power of air is very much reduced; dry-bulb 128 degrees F.; wet-bulb, 113 degrees F.; relative humidity 62. To get this excess moisture out of the fruit took considerable time under these conditions. In the meantime at the hot end of the tunnel fruit was being exposed to rapid drying: dry-bulb, 180 degrees F.; wet-bulb 112 degrees F.; relative humidity 11. The tendency was to reverse the process with attendant scorching at the high temperature.

It might be possible to work out a set of conditions at which this would not occur. The conditions would have to be very rigidly adhered to and this is not always possible in commercial operation. To overcome these difficulties a new dehydrator was built taking advantage of hot-end loading to overcome the weaknesses encountered.

DIAGRAM OF SINGLE SHORT TUNNEL WITH FINISHING CHAMBER FOR  
HOT-END LOADING



T, trucks; arrows indicate direction of air flow; R, air return duct between the finishing chamber and fan; R1, air return duct between the primary tunnel to the finishing chamber; F, conoidal fan to circulate 40,000 cu. ft. per minute in the primary chamber; F1, propellor-type fan to circulate 20,000 cu. ft. per minute in the finishing chamber; H and H1, heaters for primary and secondary ends of tunnel respectively; D, D1, D2, two-foot door to allow entrance to fans and heaters, and to make truck exchanges in the tunnels; D3 and D4, counterbalanced doors to allow intake and outtake of trucks; TP, transfer pits; V1, intake duct for use when the finishing chamber is not operating; V, intake duct; V2, outlet duct; TR, track; shading, insulation.



## THE SHORT TUNNEL WITH A FINISHING CHAMBER FOR HOT-END LOADING

The dehydrator is a modification of the single, short tunnel dehydrator. The primary tunnel is the same as the short single tunnel dehydrator and is operated in the same manner. As the trucks reach the cool end of this tunnel, they are passed on to a finishing chamber through a folding door. The finishing chamber is in line with the primary chamber so that trucks move on a straight track. In the finishing chamber half the volume of air is moved in an opposite direction to that in the primary chamber. In this case the air is heated not above 165 degrees F., so that the nearly dry fruit is not exposed to high temperature. To assure positive circulation of air a propellor type fan is used. This is driven with a small motor. In operation this air is not fully saturated and is therefore by-passed through the return tunnel, R, to the primary tunnel.

The fresh air intake, V1, is placed at the hot end of the finishing chamber and is so regulated that air may be taken from inside the building or from the outside, or both. The air outlet, V, is placed at the cool end of the primary tunnel. The air inlet and outlet ducts are connected with a large return air duct, R1, so that if air is not fully saturated it can be used again and passed from the primary to the secondary tunnel. In this manner complete recirculation can be used in both chambers.

*The Advantages of This System.*—1. Hot-end loading is used with quicker drying. The capacity of this machine is about 10,000 pounds of dried stock per 24-hour day.

2. The process is continuous.

3. The quality of the finished stock is much superior to that produced by cool-end loading. The fruit is actually dried at low temperatures. When the temperature in the dehydrator is high the fruit is giving off moisture quickly, therefore, the fruit temperature is low. When the fruit is nearly dry only low temperatures are used.

4. As air is circulated in two directions through the fruit trays, even drying is produced over the entire tray surface.

5. There is no possibility of drip occurring, as the cold fruit is loaded at a point in the dehydrator where the relative humidity of the air is very low.

6. The dehydrator is efficient, as air is only released when it is commercially saturated.

Four dehydrators of this type have been constructed: three in Nova Scotia for dehydrating apples, and one in Ontario for vegetable drying. These dehydrators are all operating satisfactorily. Modifications might easily be made to suit the building, and the finishing chamber could be placed parallel with the primary tunnel.

The dehydrator has a very large capacity. By reducing its size lower capacities could be secured. One operator drying vegetables reduced the width and height of the tunnel to cut the capacity of the dehydrator by approximately one-half. The air velocities were kept the same as in the larger tunnel.

In another case, an operator who wished maximum capacity in his dehydrator, has placed a baffle, hinged to the ceiling, at the end of the primary tunnel to scoop all the air from this tunnel through the duct above the finishing chamber. Before the air enters this chamber it is re-heated. In this case, the inlet is placed in the return duct to the primary tunnel just before the air enters the heaters and fan. The outlet duct is placed at the end of the finishing chamber. Only one fan is used and this is driven at high speed to overcome static pressure.

*The Cross-flow Tunnel.*—It has been previously shown that air in passing over prepared fruit picks up moisture quickly, which results in a corresponding drop in temperature. In the hot-end loading tunnel with a finishing chamber, the temperature is controlled at either end, but is comparatively low in the centre of the tunnel at the outlet.



Simms Foods Ltd., Berwick, N.S., have designed a vertical tunnel in which the air is carried back and forth at right angles to the direction of tray movement. The air passes over one width of trays, is turned and reheated. Another fan forces the air across the trays. This is continued up and down the dehydrator. It is claimed for this method that control is kept of temperature and humidity during all the stages of drying. Some drop in temperature must occur when the fruit is passed from one side of the tray to the other. A fine quality dehydrated product has been manufactured by this process. Unfortunately, mechanical difficulties in a semi-automatic equipment have made it impossible to fully demonstrate the process.

It is evident that further experimental work on a horizontal tunnel combining cross flow and the jet system to induce air circulation might produce a dehydrator superior to any of present design.

*Cabinet Driers.*—For the small operator the cabinet type drier would be satisfactory. A drier of this type should be constructed so that the direction of air flow can be reversed. A drier of this type constructed at the Kentville experimental station has proved very satisfactory for drying apples.

In an experimental dehydrator fruit was piled in stacks in the centre of a room-like structure with two-foot spaces between the walls, and the first and last stack on two sides and against the walls in the other direction. Air was blasted through nozzles to induce the movement of the entire air mass through the fruit. The scheme was quite successful and fruit was dried without scorching, in five hours.

## General Information on Construction

### MATERIALS USED FOR CONSTRUCTION OF A DEHYDRATOR

It is impossible to give accurate detailed instructions as to the construction of a dehydrator. These will be influenced by the type of dehydrator built and by the materials that can be secured for the purpose.

A well-insulated tunnel is necessary and one that will prevent leakage of air from the tunnel. Interlocking tile would be satisfactory for this purpose. The dehydrators in Nova Scotia have been made of frame construction, using 2- by 4-inch lumber for framing. The inside of the tunnel has been lined with some form of one-half-inch fibre board or material with equal insulating value. The outside of the tunnel has been enclosed with tongue-and-groove sheathing. To protect the insulation tongue-and-groove flooring has been used to line the tunnels. To prevent air leakage all lumber used must be specially selected from knot-free stock and must be thoroughly kiln dried.

It is important that the trucks fit the tunnel walls closely to prevent air by-passing around the trucks. To hold two trays three feet wide, the trucks will be 6 feet  $1\frac{1}{2}$  inch wide, outside measurement. The tunnel would then be 6 feet  $3\frac{1}{2}$  inches wide, inside measurement, to allow one inch clearance on each side of the trucks.

Wooden baffles may be placed above the position of each truck in the dehydrator if too much air is passing between the top of the trucks and the ceiling.

The return air ducts should be sufficiently large to allow free passage of air at moderate velocities. For a tunnel 6 feet wide by 7 feet high, or with a cross section of 42 square feet, the return ducts should be at least half this in cross section. They should be well insulated to prevent heat loss.

Doors should be constructed to be air tight. A counter-balanced door, fitting into grooves on each side and lifting vertically, is a very good type. They should be sufficiently wide to allow free passage of the trucks in and out of the dehydrator. For this purpose four inches clearance should be allowed on one side and on the other, two feet. This allows sufficient room for the operator to get in behind the trucks to make the transfers.

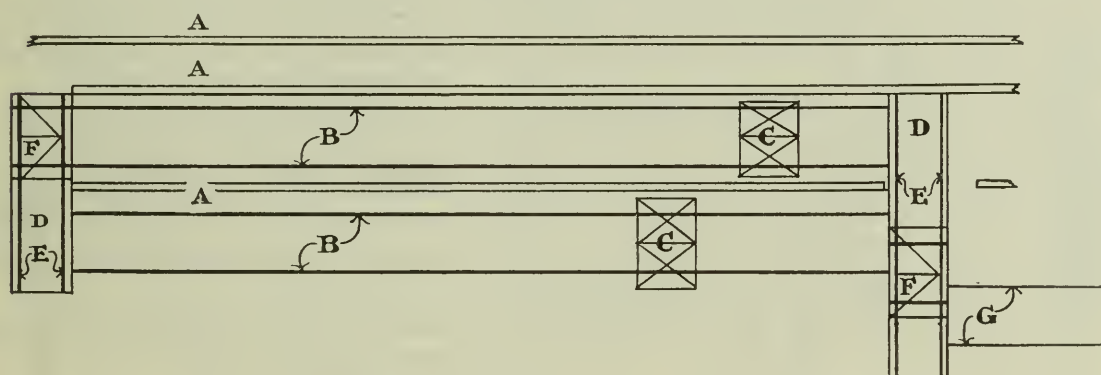
Inlet and outlet ducts need not be insulated. They should be sufficiently large to allow free passage of air to and from the dehydrator. An outlet the full width of the tunnel and three feet across is satisfactory. Care should be taken that the space between the top of the duct and the protecting roof is equal in area to that of the duct.

Dampers should be placed in both intake and outlet ducts so that the amount of fresh air flowing into the dehydrator can be carefully regulated. These can be hand-operated or so equipped that they operate automatically and do not open until the required saturation of air is reached.

In the original plan a door was placed between the primary and secondary tunnels to divert the air from the finishing chamber to the primary intake. This door has been found unnecessary. Instead, a hinged damper is placed at the outlet duct with its lower edge facing the flow of air from the primary tunnel. This catches the air from the primary tunnel and diverts it upward to the outlet, and through the return duct to the finishing chamber. This ensures that only the more saturated air from the primary tunnel is released. The amount of air so diverted is regulated by raising or lowering its outer edge. The damper is the whole width of the tunnel and five feet long.

The floor can be built of concrete or matched lumber. It must be strongly supported as each truck fully loaded weighs about 2,000 pounds. The trucks are best handled on light-gauge rails. These can be imbedded in concrete or placed on the floor with an additional floor covering of one inch to hold them in place and to bring the top of the rail only slightly above the general floor level. The trucks are best handled in and out of the dehydrator on transfer trucks according to the following diagram.

DIAGRAM TO SHOW RAIL AND TRUCK TRANSFER, ARRANGEMENT FOR A DEHYDRATOR



A, dehydrator walls; B, fruit truck rails, four feet apart to handle fruit trucks C; D, transfer pit  $10\frac{3}{4}$  inches below ordinary floor level, with rails, E, three feet apart to carry transfer trucks F; G, extensions that can be made to any convenient point for loading or unloading from either pit. Rails are marked in heavy line. Scale 10 feet to 1 inch.

At each doorway the floor is lowered  $10\frac{3}{4}$  inches to the width of the transfer trucks. This extends to the back wall of the tunnel and out in front of the dehydrator to allow for transfer of the trucks in the tunnel and in front of the dehydrator.

#### EQUIPMENT FOR HEAT AND ENERGY

Radiation and heat requirements are entirely dependent on the capacity of the drier and the conditions of operation. If these are known a manufacturer can specify exactly what equipment will be satisfactory.



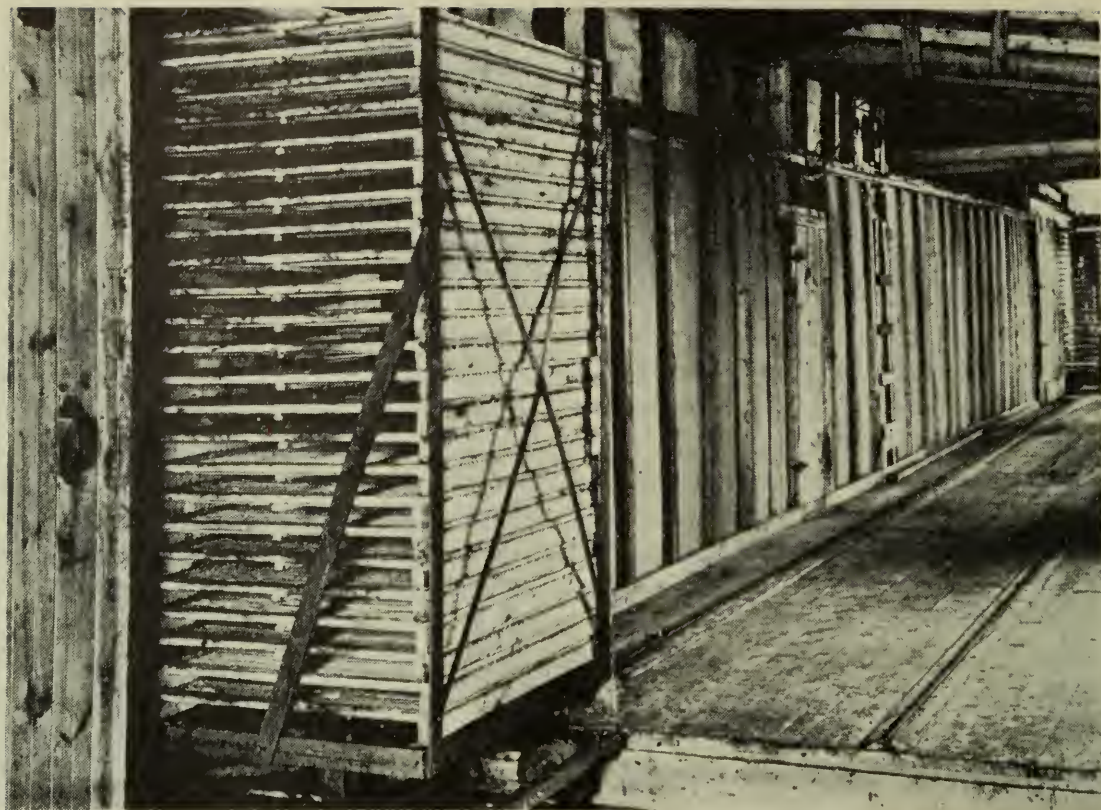


FIG. 1.—A commercial dehydrator with a finishing chamber for hot-end loading. In the foreground at the left is a truck being removed from the finishing chamber. The pit to carry the transfer truck and the rails is shown. In the centre top is shown the recording thermometer at the position of the outlet duct. At the far right a truck is shown entering the hot end of the tunnel.

*Radiation.*—Under most Canadian conditions steam is the most satisfactory source of heat, as the dehydrator is placed in a building which includes paring room, curing room, etc., which have to be heated during the cold manufacturing months.

In the early days of dehydration cast-iron heaters were used to provide radiation. More recently the fin-type heater has come into use. These are much more satisfactory as they are light in weight, give rapid heat transfer and require no extra space in the dehydrator. The cast-iron radiators in addition to requiring a special heating chamber and being heavy and bulky, offer a greater resistance to air flow.

To determine the amount of radiation necessary, the following information is required:—

- (a) The volume of air to be heated per minute.
- (b) The temperature range through which the air is to be heated.
- (c) The steam pressure to be used.

*Example.*—A single short tunnel dehydrator is to be built, the fan to be run at 450 R.P.M. and to have a capacity of 40,000 cu. ft. of air per minute at two inches static pressure. At the hot end of the tunnel 170 degrees F. is to be the maximum temperature and 45 degrees temperature is the maximum drop that can be expected from the hot to the cool end. A maximum of one-third of this air is to be released and outside air is brought in to replace it. The radiation requirement for the air brought from the outside of the dehydrator will have to be figured on the minimum temperature conditions that can be expected during any period of operation. This for the purpose of computation will be placed at 0 degrees F.

The following information is then available. One-third of 40,000 cu. ft., or approximately 13,300 cu. ft. of air per minute must be heated from 0 degrees



F. to 170 degrees F. Two-thirds of 40,000 cu. feet, or 26,700 cu. feet, per minute must be heated from 125 degrees F. (temperature drop in tunnel) to 170 degrees F.

The steam pressure, as previously stated, is 100 pounds. The manufacturer then can figure the amount of radiation necessary according to the rate of heat exchange secured from the particular type and make of heaters. In addition the boiler horse-power requirements for heat can be determined.

*Energy.*—Manufacturers, in addition to providing information as to capacity of their fans at different speeds and static pressures, give the horse-power requirement under any given set of conditions. Whether or not a steam engine would be more satisfactory than an electric motor to drive the fan would depend

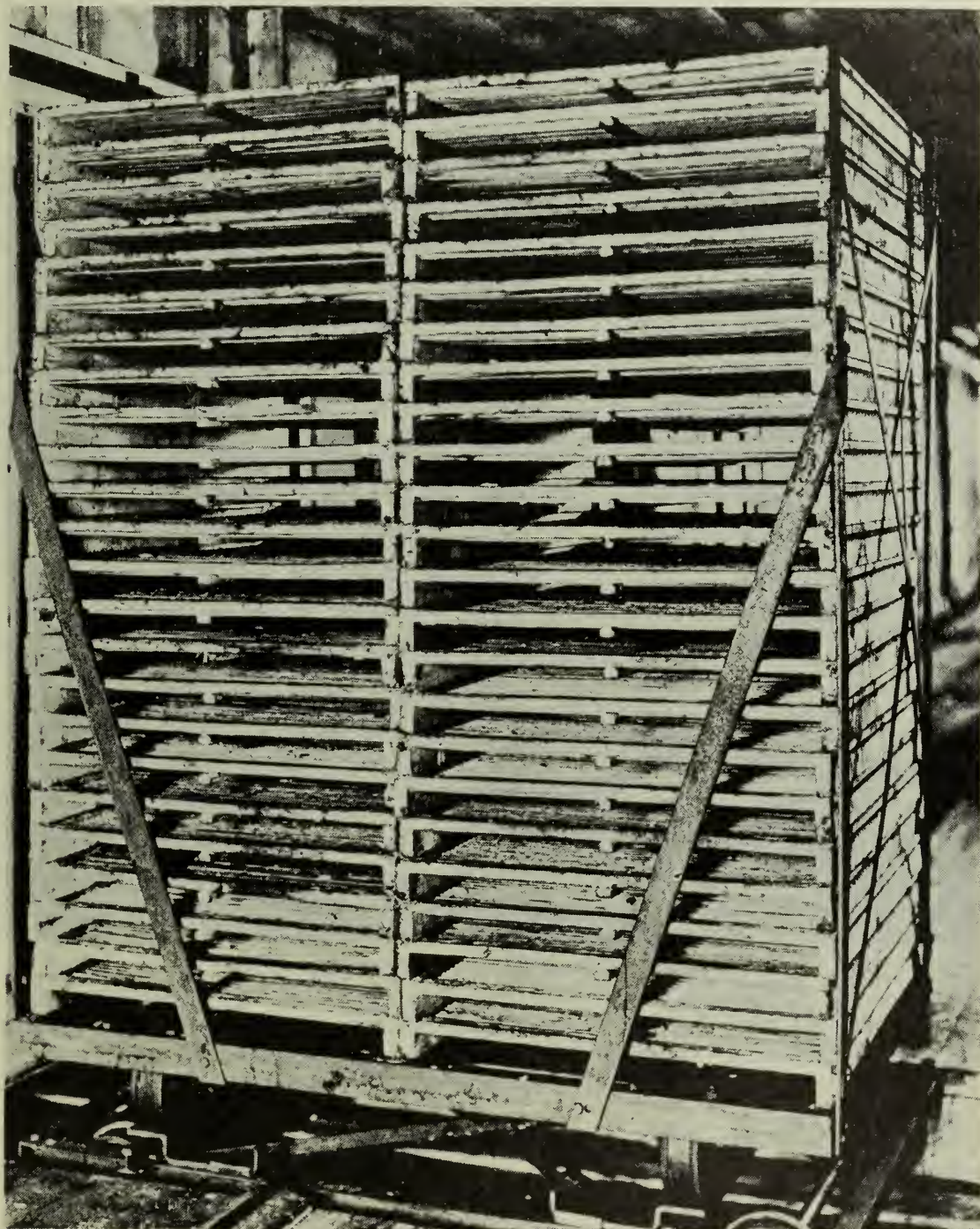


FIG. 2.—Back view of a truck with trays in place. The frame keeps the trays in rigid position. The grooved wheels fit over the rail. The truck is standing on the rails of the transfer truck. Note the arrangement for blocking the wheels while the truck is being moved from one position to another.



on the relative cost for power purposes. Where steam is used to drive the fan and the exhaust steam is used through low-pressure heaters to provide heat in the dehydrator, energy costs are reduced to a very low figure.

The boiler capacity will depend on conditions as stated. No advantage is gained by installing a boiler that has just sufficient capacity to handle the job. For the dehydrators mentioned in this bulletin from 30 to 100 H.P. is required depending on the conditions of operation.

### TRUCKS

In most dehydrators, trucks are used for carrying the trayed fruit through the dehydrator. These may be of two types: they may be operated on tracks, or may be mounted on caster wheels so that they can be taken to any part of the building for loading and unloading. In a truck four feet by six feet with two stacks of trays 24 tiers high there is considerable weight of fruit and the rail system favours easy handling.

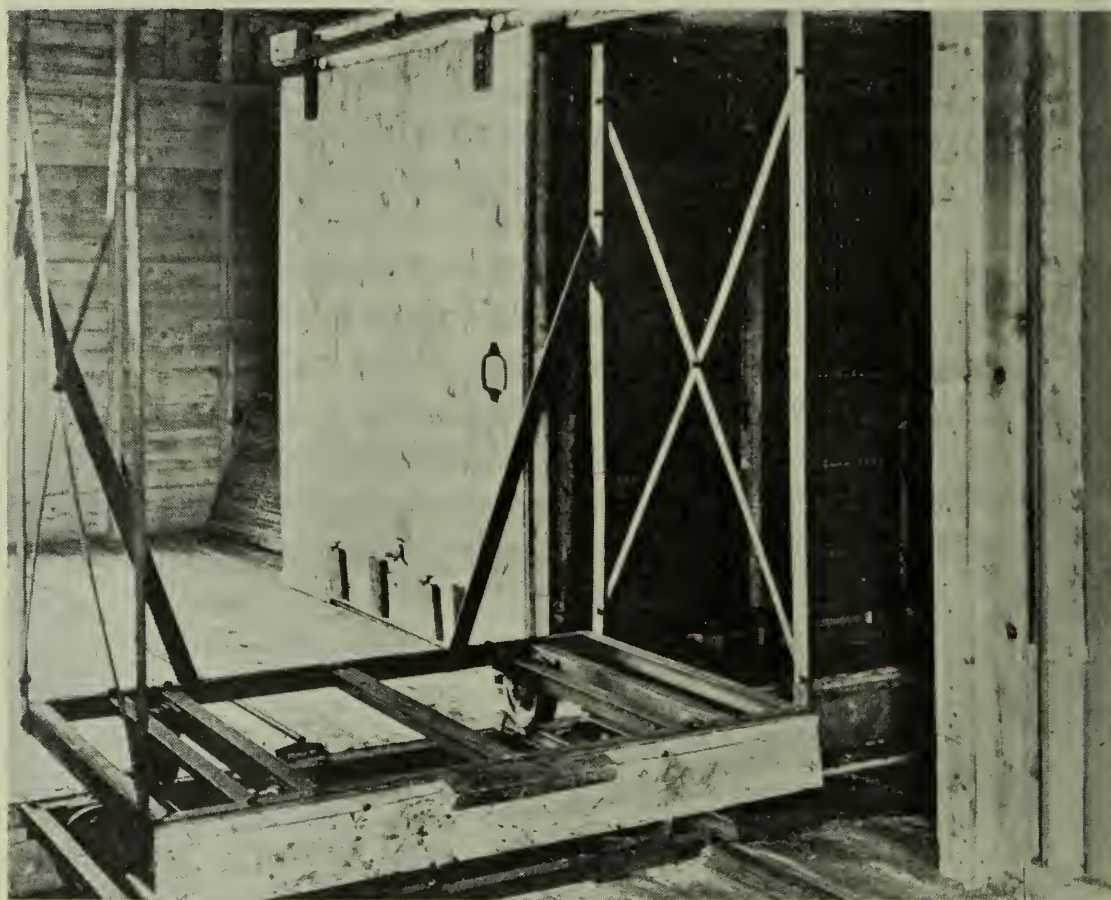


FIG. 3.—Front view of a truck. The baffle boards and spacer are in place in front of the truck. In the background is the sliding door with a flap which closes the transfer truck pit when the door is in position. Through the door, the fin-type heaters for the finishing end of the tunnel can be seen.

*(Courtesy of the Nova Scotia Steel and Coal Company Limited)*

The truck is built with angle iron to keep the trays in rigid position. One side and the two ends of the truck are framed with iron strapping. The one side is left open for convenience of loading.

Air by-passing under the trucks very often cuts down dehydrator capacity. To overcome this a sheet-iron baffle should be welded in the centre of the truck to go well up under the tray and to just clear the rails and floor. This should be the entire width of the truck.



Trays from one truck should not butt against those of the next truck. Due to wear trays vary in height and when this condition is met overlapping of trays may seriously impede air flow. A four-inch air space between trucks allows air flow to equalize and prevents air blockage from this source. This can be easily accomplished by bolting a 2- by 4-inch scantling on its edge to one side of each truck, or by welding 4-inch metal spacers on the trucks.

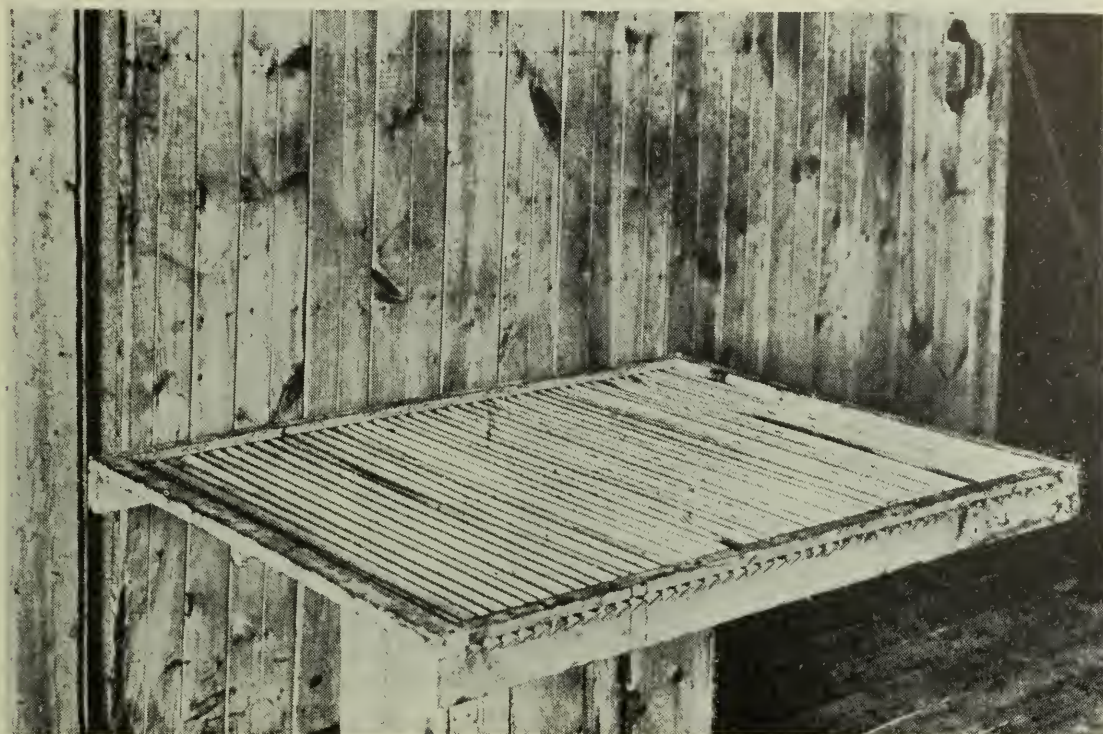


FIG. 4.—A single tray showing details of construction. Note the triangular slots placed in the side pieces at an angle, to baffle air through the fruit.

*(Courtesy of the United Fruit Companies of Nova Scotia)*

#### TRAYS

For apple dehydration trays should be constructed entirely of wood. A very good size is 3 feet by 4 feet, which allows two tiers to be stacked on a 4-foot by 6-foot truck. The surface of the tray should be slatted. Narrow wooden slats are placed in grooves in side pieces  $2\frac{1}{4}$  inches high and  $1\frac{1}{2}$  inches thick nailed in position. A space of  $\frac{5}{16}$ -inch is left between the slats. For pomace drying this space is reduced. A piece 1 inch by  $1\frac{1}{2}$  inches is then nailed over the ends of the slats to the side piece to make the sides  $3\frac{1}{4}$  inches high. End pieces 1 inch by 2 inches are mortised into the sides to give rigidity to the tray. Cement-coated nails resist the action of sulphur fumes and should be used.

In constructing trays, only the very best kiln-dried lumber should be used as green lumber shrinks and the trays soon loose their rigidity. The slats must be treated with hot beef or mutton tallow to prevent sticking. The trays should be warmed before they are treated and then placed in the dehydrator so that the tallow will soak into the pores of the wood.

#### TEMPERATURE CONTROL AND INSTRUMENTS

To produce a high-quality product under conditions of economical operation, it is necessary to have accurate control of the conditions of dehydration. This can only be done with control instruments and by keeping an accurate record of the air conditions during the operation of the dehydrator. Records can be used as a check on the plant operator and if at any time a poor-quality product is produced a complete set of records should reveal the reason.



The temperature of the air at the hot end of the dehydrator should be controlled. This can be done by hand or, much more accurately, by the use of automatic equipment.

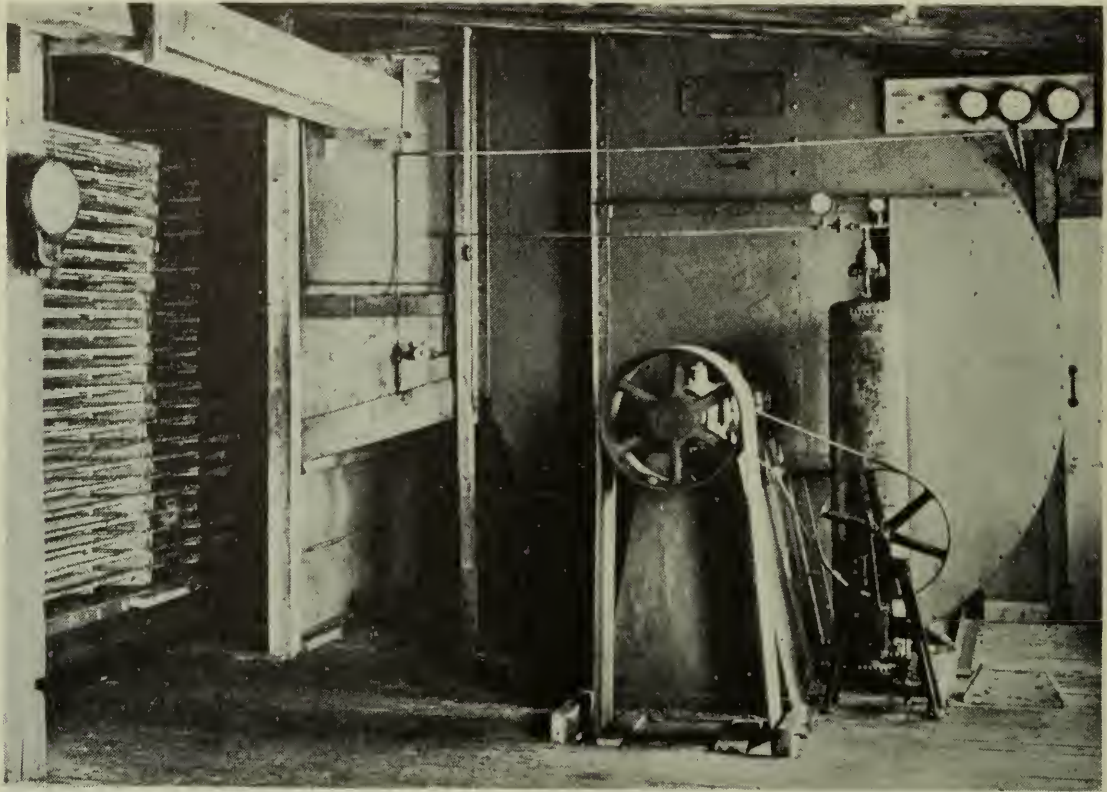


FIG. 5.—The hot, or fan end of a tunnel. The fan is shown with the steam pressure recording gauges at the upper right of the picture. Immediately behind the fan, but not shown, are the fin-type heaters. The tank and air pipe are connected to a diaphragm valve and to a temperature regulating device which is shown at the centre of the picture. The recording thermometer for this end of the tunnel is shown at the upper left.

Instrument manufacturers make equipment for this purpose.

A recording dry-bulb thermometer should be placed at this end of the tunnel to accurately record temperature of the air entering the fruit. In the hot-end loading tunnel with a finishing chamber, a recording thermometer should be placed at each end of the dehydrator. In the primary tunnel this will show whether or not the required amount of heat is being supplied. In the finishing chamber the bulb of the thermometer should be placed so that it records the temperature of air immediately before it enters the fruit. Temperatures above 165 degrees F. at this point will cause scorching. Automatic temperature control would be of value for this.

In all dehydrators a wet- and dry-bulb recording thermometer should be placed immediately before the outlet duct. As previously stated control of the outlet air very largely regulates the fuel cost for dehydration. A complete record at this point will largely explain heat losses and determine the amount of air to be released. When air is not commercially saturated, outlet and inlet dampers should be closed. When commercial saturation is reached the dampers should open sufficiently to maintain this.

The anemometer is used for determining air velocity and is of value to the operator of a dehydrator. While it is not as accurate as the Pitot tube it is more easily operated and does give comparative results. The maintenance of air velocities is important to rapid dehydration. Evenness of air flow and by-passing of air can be determined; in fact any factor relative to rate of air flow at any point in the dehydrator.

In use one- to five-minute readings are taken. It is not sufficient to take one reading to determine air flow. For example, if the air flow through the main tunnel is to be determined readings should be taken at fixed points from the top to the bottom of the dehydrator and from side to side. The results can then be averaged. If the anemometer is checked for error at different intervals by the maker the results should be sufficiently accurate for this purpose.

### Details of Operation

The principles underlying the operation of a dehydrator have been considered. From this, the details of operation are easily understood. If the short-tunnel dehydrator with the finishing chamber is considered, operation would be as follows: when the first truck is loaded it is placed in the dehydrator. Steam is turned on the heaters that supply the primary tunnel only. The fan is started. The temperature is set at the hot-end at 180° degrees F. Readings of the dry- and wet-bulb thermometers at the air outlet show that saturation is not reached so the damper is kept closed.

As soon as the next truck is loaded, which should be in 30 to 45 minutes, the fan is slowed down, the doors opened and the truck added at the hot-end. This is repeated until the primary tunnel is full.

Commercial saturation of air does not ordinarily occur till after two or three trucks have been added. Sufficient leakage occurs around doors, etc., to carry away the moisture as fast as it is evaporated. Examination of the wet- and dry-bulb thermometer and the determination of the relative humidity of air by the use of the relative humidity chart will determine when this is reached. At this point the outlet duct is partly opened to release some of the saturated air. Air will not be brought in through the intake duct unless the fan in the secondary tunnel is started. It is therefore an advantage to have a small intake duct cut in the return duct to the primary tunnel just before the air passes through the heaters to the fan. This should be three feet by three feet, and is provided with a damper that will completely close the duct. This is opened to bring in fresh air as required, and is not used after the fan in the secondary tunnel is started. When the primary chamber is full and another truck is ready for the dehydrator, the end truck in the primary chamber is moved to the finishing chamber and the other truck introduced. Both fans are placed in operation. The inlet damper that has been used up to this time is closed. The regular inlet damper is partially opened and the hinged baffle, just below the outlet, is partially lowered to divert air to the outlet and back to the finishing chamber. The extent to which the outlet damper is opened is, of course, regulated by the humidity of the outgoing air. The temperature at the hot end of the finishing chamber is set at 165° F.

As each truck is added to the hot end of the primary chamber, one is passed on to the finishing chamber. The dampers in the ducts are regulated to prevent heat loss.

As each truck is added, the end truck in the finishing chamber is examined and as soon as it is dry enough by feel it is removed even though the finishing chamber is not full. In practice it is found that there may be from two to five trucks in the finishing chamber depending on the rate they are added at the hot end.

When the drier is full and the dampers are finally set usually very little change has to be made in their adjustment.

The single short tunnel is operated in practically the same manner as the primary tunnel up to the time the finishing chamber is brought into use. The differences are that it is loaded from the cool end and the maximum temperatures at the hot end cannot be in excess of 170 degrees F.



## OTHER FACTORS IN DEHYDRATION

### Storage

Large supplies of apples are received by the manufacturers during the fall season. These are usually dumped in large piles on the ground at the plant. These piles are exposed to weather and heating and much loss usually occurs.

To get value from this material the more important varieties should be separated out and at least stored under cover in bins with a slatted floor raised from the ground, or better, in half-barrel lug boxes. The fruit in bins should not be piled more than four or five feet deep. Careful and adequate ventilation is necessary to take advantage of cool weather to keep the fruit at low temperature. Many manufacturers are of the opinion that fruit can be kept best out-of-doors. This idea has developed from the fact that most of the factory storages are cellars where little provision has been made for ventilation.

### Washing

Fruit should be washed before peeling to remove grit and dirt. A well-constructed concrete tank with water in continuous flow makes a good washer for this purpose.

### Paring and Coring

Various types of equipment are on the market for this purpose. Where seed-cellars are not used to get rid of the seed carpels from the core of the apple the standard  $\frac{5}{8}$ -inch coring knife is not large enough with most varieties to produce carpel-free rings. For apples  $2\frac{1}{4}$  inches and over, a  $\frac{7}{8}$ -inch coring knife leaves very much less seed cell although the waste is increased by about ten per cent. Where this is used for pressing or is dried and sold, this loss is not very great. The improved product should more than compensate for the loss.

### Seed Celling

One of the greatest faults of the average Canadian product is the high percentage of rings containing pieces of seed cell. The larger coring knife is only a partial solution. Modern equipment that will remove the core area entirely is necessary to make the best grades.

### Slicing

Fruit may be sliced into rings or into quarters, sixths, or eights. The most commonly used system is ring slicing. Quicker drying results in the ring form as a larger surface is exposed to evaporation. Machinery is available for this purpose.

### Sulphuring

It is necessary to bleach apples with sulphur before drying. This may be done either as a gas or by first combining sulphur dioxide with water and using the solution as a bleach. The common method is to use gas. Sulphur is burned in a specially constructed stove. The fumes are carried from this to the bleacher. This may be a slatted conveyer inside a gas-tight box for bleaching whole apples, or a cabinet for holding the trays of apples for bleaching the slices.

The endless conveyer is usually 30 inches wide and made of slats 1 inch by 2 inches, close enough together to prevent apples and apple pieces from going through and yet to allow free passage of the gas through the fruit. The slats are fastened to endless-link chains which are driven from a worm gear. The gear ratio is such that the fruit moves the complete length of the chamber in the bleaching time required. The conveyer is usually about 40 feet long. The

whole arrangement is enclosed in a gas-tight box. Gas is introduced from the sulphur stove at the same end at which the pared, whole apples are introduced. A chimney is provided at the other end of the box to carry the fumes away and to create a draft. The apples are usually fed to the box from an endless conveyer. The whole arrangement can be slung from the ceiling or placed on the roof and the apples fed to the slicer by gravity.

A sulphur chamber for sulphuring fruit in the slice can be very simply made in a gas-tight manner to hold one or two trucks of fruit.

There is bound to be more or less leakage of gas from either arrangement. As the fumes of sulphur are very irritating the sulphuring equipment should be in a room separate from the paring room. In any case a small blower fan to frequently change the air in the room where the cabinet or conveyer is placed makes for much better working conditions.

Apple flesh very quickly discolours by oxidation when exposed to air. Sulphur fumes act to bleach out these discoloured areas and by combining with the water in the slice prevent discoloration during the drying operation.

Thorough impregnation of sulphur is necessary to a good natural-looking ring. As whole apples they should be exposed to heavy sulphur fumes for at least 45 minutes; as rings 30 minutes will produce excellent results. At the experimental station, Kentville, best results have been secured by sulphuring the rings. In any case it is necessary that the fruit should be exposed to sulphur fumes as soon after paring as possible in order to prevent browning. If this can not be done, spraying with a five per cent salt solution will retard discoloration and shorten the required time of bleach.

### Re-sulphuring

During the dehydration operation most of the sulphur is lost from the fruit. Particularly with fall fruit discoloration occurs after the fruit is dried. The rate of discoloration is affected by exposure to light, heat and by the moisture content of the fruit.

Tests at the experimental station, Kentville, with the variety Gravenstein at different moisture contents have given the following results. Where re-sulphuring was practised the equalized rings were spread evenly on a canvas belt and exposed for 20 minutes to the fumes of burning sulphur in a sulphur chamber.

THE EFFECT OF HEAT, LIGHT, MOISTURE AND RE-SULPHURING ON THE DIS-COLOURING OF RINGS IN STORAGE

Lot number	Nearest moisture content	Original colour	Final colour			
			After 3 months storage		After 14 days direct sunlight	After one month to indirect light
			At 40 to 50 degrees	At 65 to 70 degrees		
			Not re-sulphured.			
1.....	25	10	8	6	Pink	5
2.....	15	10	8	7	Pink	8
3.....	11	10	9	8	Pink	8
			Re-sulphured.			
1a.....	25	10	10	10	10	10
2a.....	15	10	9	8	Slightly pink	9
3a.....	11	10	9	8	Pink	9

The numbers show the amount of discoloration that took place. Ten indicates rings with original natural colour, nine very slightly browned, eight slightly browned, etc., down to five where dark brown rings resulted.



A low moisture content tends to preserve natural colour. High temperature and light tend to accelerate the rate of browning. Direct sunlight turns the rings pink. Sulphuring the fruit after it is dried tends to preserve colour but the effectiveness of sulphur is dependent on the moisture content of the dried fruit. This is to be expected as moisture is necessary for the absorption of the gas. Where fruit is dried to the legal tolerance, 25 per cent or slightly below, and particularly with fall fruit, re-sulphuring should preserve the natural colour of the fruit until it is marketed.

A re-sulphuring device can be made in the same manner as the endless conveyer for sulphuring apples, except that the slats must be close together, or a canvas belt can be used. This conveyer is not required to handle the same volume of material and can be built about half the width and as only 20 minutes are required for re-sulphuring the conveyer does not need to be as long.

### Curing

After fruit is dried it should be cured to equalize moisture in the rings. Some rings are always on the dry side, others are too wet. These wet rings would ultimately start deterioration if the moisture were not equalized. A curing room should be provided with bins, good hardwood floors, and should be heated so that the humidity of the air can be partly controlled. The rings should be piled not more than four feet deep in an even manner over the floor of the bin and turned over every 24 hours until thorough curing has taken place. The drier rings will absorb moisture from the wetter rings, and vice versa. If a bin is too wet or too dry, a dry or wet batch can be taken from the dehydrator and worked in to lower or raise the moisture content as desired. Usually, at best, a week is required for curing.

### Screening

The product after curing should be thoroughly screened to remove chips, seeds, and seed carpels. Many chips are left in the product when a fine mesh screen is used. A screen with one-inch mesh is satisfactory. The rotating type of screen breaks up lumps of rings and gives sufficient screening to remove a very large percentage of the chips. The chips should be again screened through a  $\frac{5}{8}$ -inch-mesh screen to remove seed carpels and seed.

Clean chips are usually only slightly less valuable than whole rings. The removal of chips improves the appearance and grade of the original product and should more than pay for the loss in volume.

## SUMMARY

1. In Nova Scotia many varieties are grown; a few of these represent the largest bulk of the crop. These few varieties should be kept separate for dehydration purposes.

2. The varieties most desirable for dehydration are Baldwin, Ben Davis, and Wagener for white stock; Gravenstein, King, Fallawater, Nonpareil and Northern Spy for light golden stock.

3. Early fall varieties are not suitable for dehydration. Size of fruit has an effect on the cost of preparation and affects the quality of the product produced. Small sizes are more expensive to prepare than larger sizes and produce more chips in the finished product.

4. Apples two and one-quarter inches in diameter and less are uneconomical to pare.

5. Reasonably sound fruit is necessary for dehydration; all rotten, badly pitted or deformed fruits should be removed as they slow up preparation and lower the grade of the finished product.

6. Apples should be bought on a grade basis for dehydration and not as straight run of cull fruit.

7. The dehydrator has many advantages over the evaporator in producing dried apples. It is more economical to operate, more sanitary and where steam is used there is less fire hazard.

8. Its principal advantage is that through carefully controlled conditions of air velocity, heat and humidity, quick drying results and a quality of finished stock can be produced that is much superior to stock from an evaporator.

9. Air acts in two ways in a dehydrator: first, to carry heat to the fruit; and second, to carry moisture away from the fruit to the outside of the dehydrator.

10. Heat acts to evaporate water from the fruit. Its action is governed by definite physical laws.

11. Humidity is expressed as a relative quantity. In general, high humidity is associated with slow drying. Commercial saturation of air before it is released to the outside of the dehydrator is necessary for economical operation. This should be in excess of 65 relative humidity.

12. The critical stage of drying is at the close of the drying period. When the fruit is nearly dry, its temperature is near that of the dry-bulb thermometer. At this stage high temperatures (above 165 degrees F.) produce browning.

13. In a cabinet drier best quality was produced and quickest drying resulted where comparatively high temperatures were used in the early stages of drying and low temperatures were used just before the finish.

14. The double tunnel served by one fan has not been as successful as the single tunnel for the drying of apples.

15. The single tunnel, properly operated, makes a very efficient unit for apple dehydration.

16. Even air flow is essential to uniform drying. Air should be carefully baffled to force it through the trucks of fruit. Air by-passing around the trucks slows up the drying operation and may affect the cost of drying seriously.

17. Pared apples give up their moisture readily. A long tunnel seriously affects quality and slows up the drying operation. With air circulating at approximately 1,000 feet per minute through the dehydrator the ideal load was found to be six trucks, or with air circulating over 24 feet of fruit.

18. Two pounds of prepared fruit to the square foot of tray surface gives even and efficient drying when fruit is evenly trayed over its surface.

19. Cool-end loading in apple dehydration is theoretically wrong, as it supplies low heat at the start of the drying process and high heat at the finish.

20. Hot-end loading is theoretically the correct method as it supplies high heat at the start and low heat at the finish of the drying process.





21. Hot-end loading in the single, short tunnel demonstrated that a much superior product can be made by this method.

22. Difficulties were experienced in this dehydrator that made the method impracticable.

23. By the addition of a finishing chamber these difficulties were overcome and an efficient unit for hot-end loading was produced.

24. Storage facilities are necessary for a dehydration plant under Canadian conditions to prevent loss of fruit.

25. A marked improvement of grade could be effected by more care in coring and seed-celling fruit.

26. Sulphuring is necessary to bleach fruit before drying. More effective sulphuring has been done experimentally in the slice than with whole apples.